ELECTRON CLOUD EFFECTS AT APS

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OUTLINE

- Introduction
- Major findings
- Measurements
- Analysis
- Summary

INTRODUCTION

WHY STUDY ELECTRON CLOUDS IN THE APS STORAGE RING?

- Aluminum chambers, whose SEY > 1
- Big effect expected, but no evidence of electron cloud-induced instability prior to studies
- Large harmonic number (1296) and flexibility in varying bunch current and temporal distribution
- Opportunity to study with positron and electron beams (7 GeV)

GOAL OF STUDIES AT APS

- Characterize electron cloud for better prediction of conditions favoring beam instability
- Provide realistic limits on input parameters for existing models: photoelectron yield, SEY, space charge effects, reflectivity

INTRODUCTION (cont)

SUMMARY OF MAJOR FINDINGS AT APS

- Strong dependence of electrons on detector location
- Energy analysis of cloud enables distinction between primary and secondary components of distribution
- Beam-induced multipacting observed for BOTH positrons and electrons (lower amplification for latter)
- Bunch current-dependent saturation of electron cloud over bunch trains
- Surface conditioning effects
- Collective horizontal motion for long e+ bunch (ECI or normal impedance?)
- Pressure rise resulting from multipacting reduces the beam lifetime

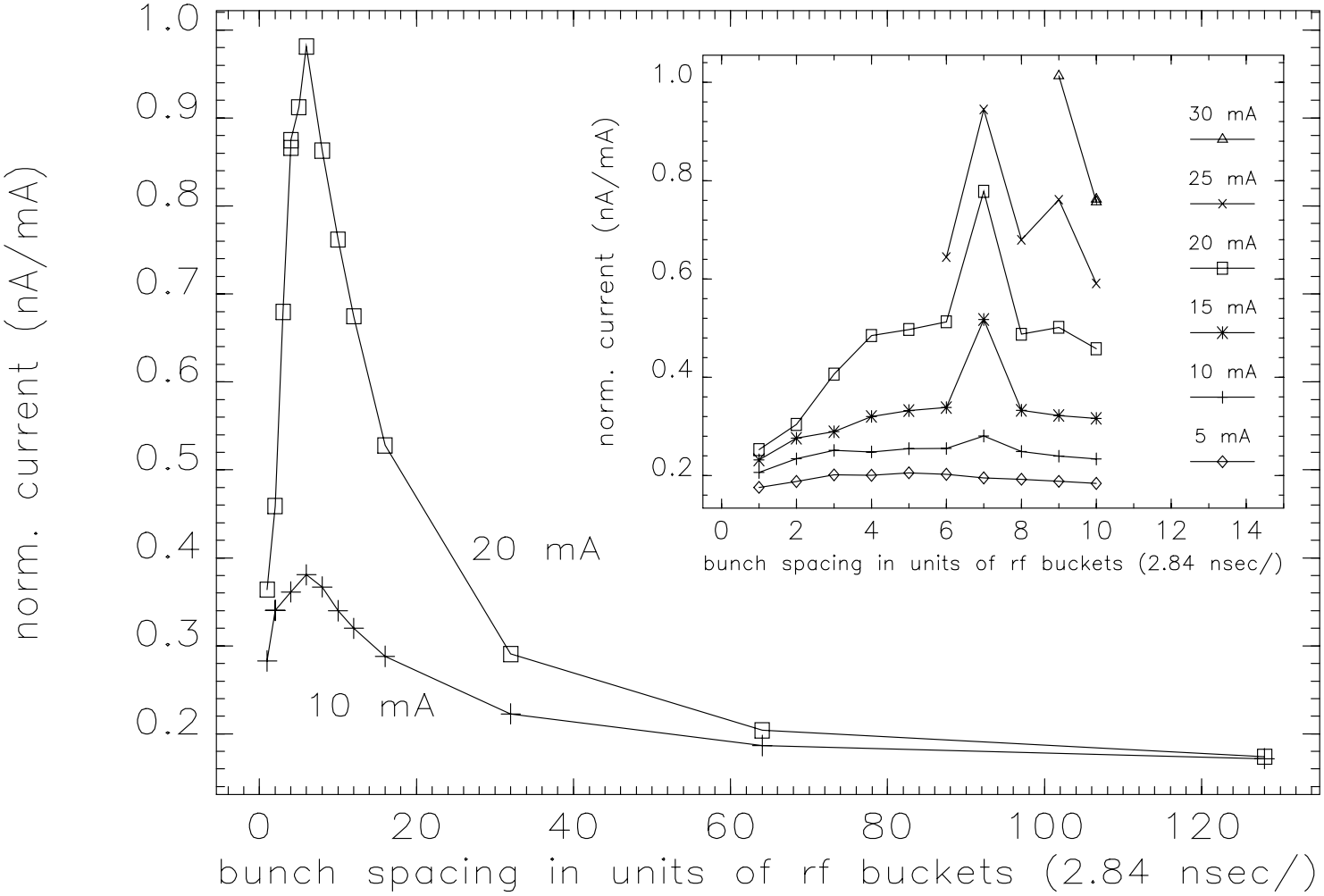
MEASUREMENTS AT APS

EXPERIMENTAL SETUP

- 10 electron energy analyzers; 3 targets (Cu, Al, TiN)
- mounted on 5-m straight modified chamber (sector 30)
- local vacuum pressure
- collector current vs. retarding grid bias voltage (-300 V to +60 V)

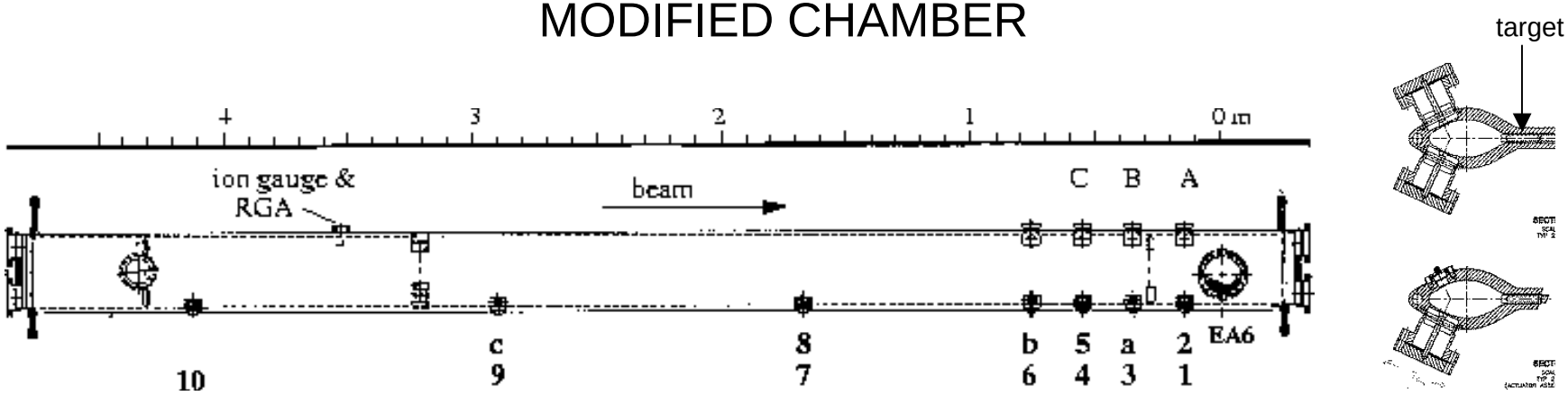
MEASUREMENTS

- vary bunch current (1 - 4 mA/bunch) and spacing (min. 2.84 ns (0.85 m))
- time-integrated electron detector signals 1 - 15 nA/mA; target signals ~5μA/mA
- electron beam stored at present; collected data for positron beam prior to Oct 1998

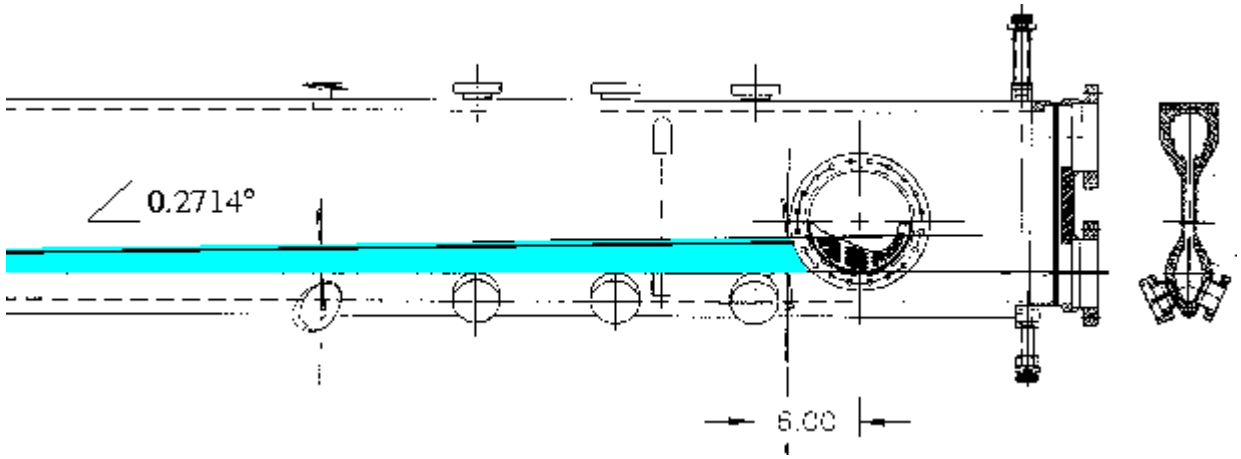


Comparison of normalized current as a function of bunch spacing and current (10 bunches total)

MODIFIED CHAMBER

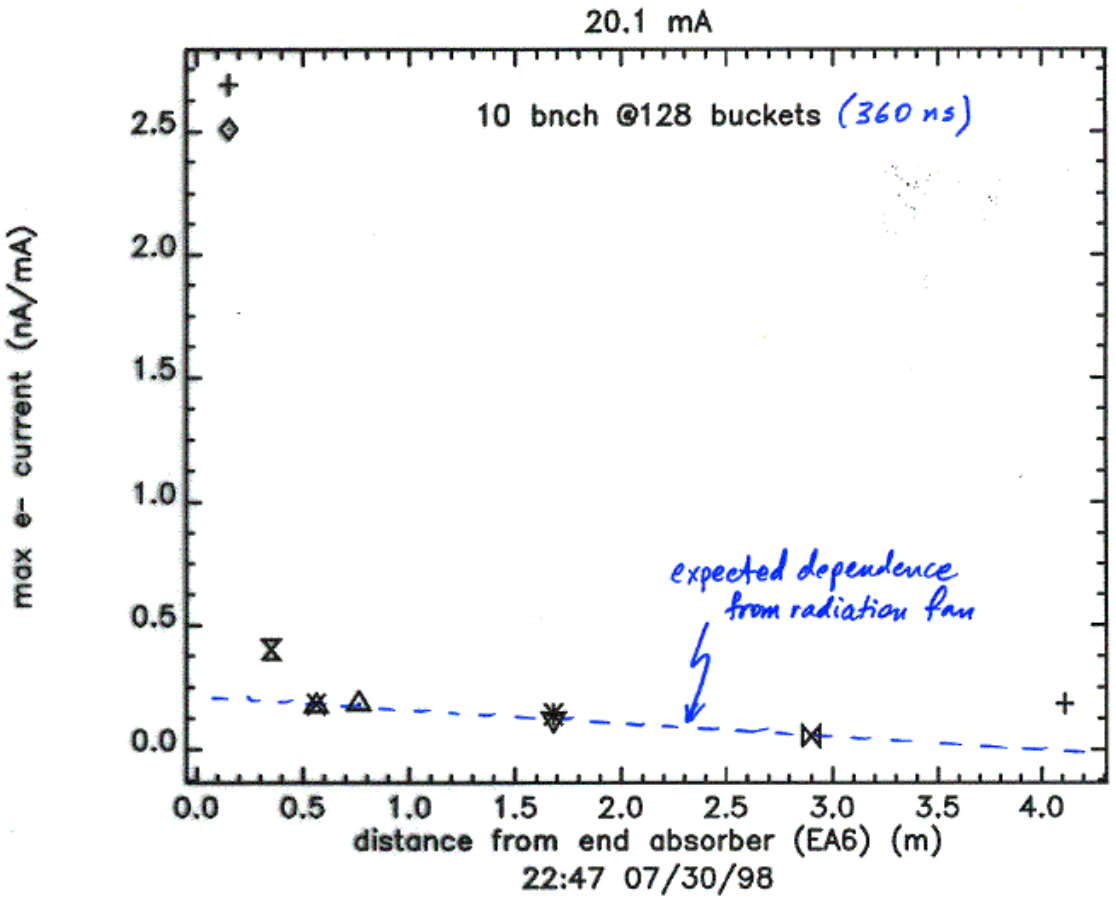


Modified chamber (top view) showing locations of: electron detectors 1-10; BPMs a, b, and c; and targets A, B, and C. On right is cross-section schematic showing target & mounting of detectors/BPMs.

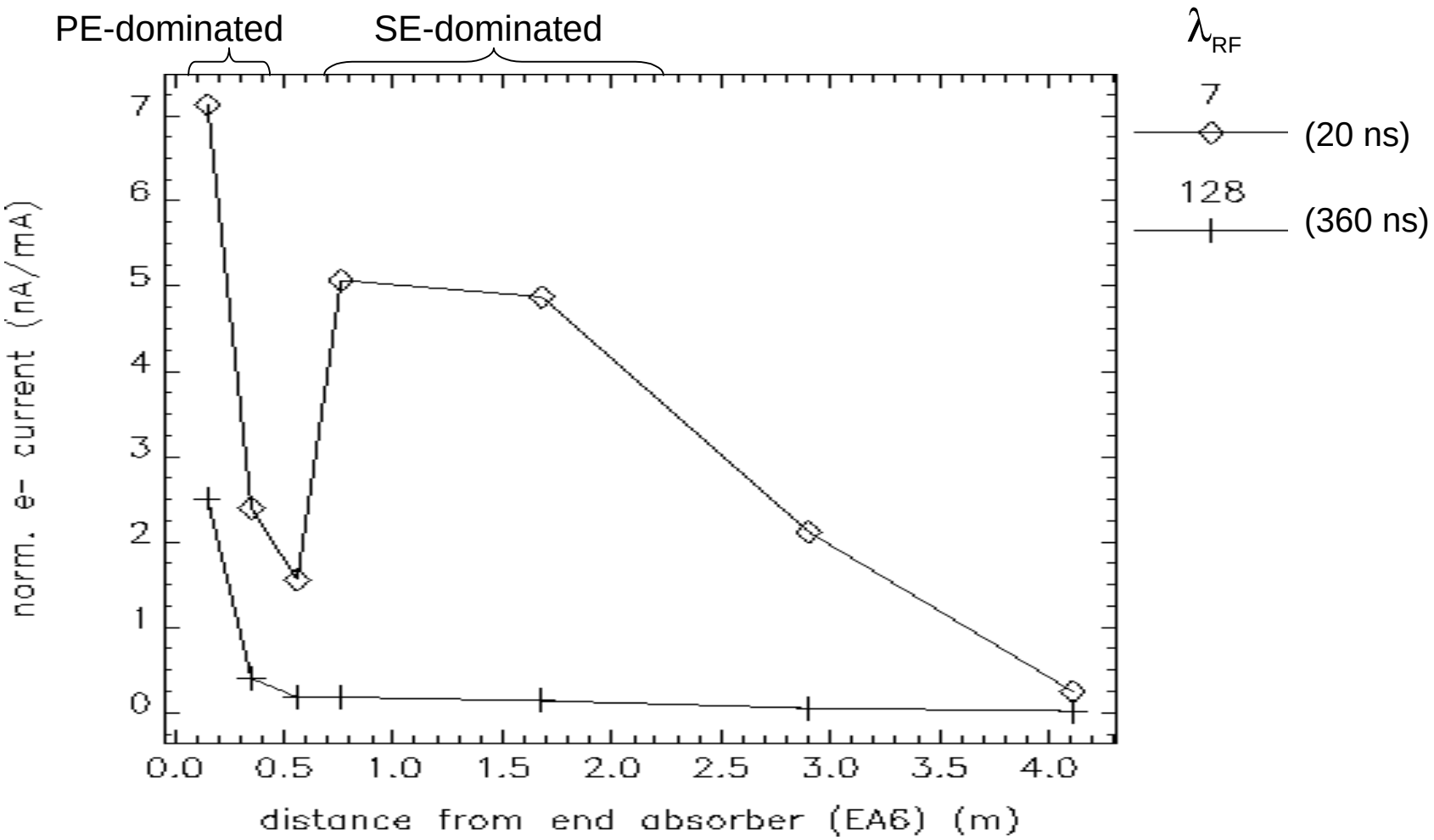


Synchrotron radiation fan at electron detectors 1-6; det 1 is 15 cm upstream from end absorber (EA6)

End absorber (EA6) a source of electrons, dominating detectors 1 - 3



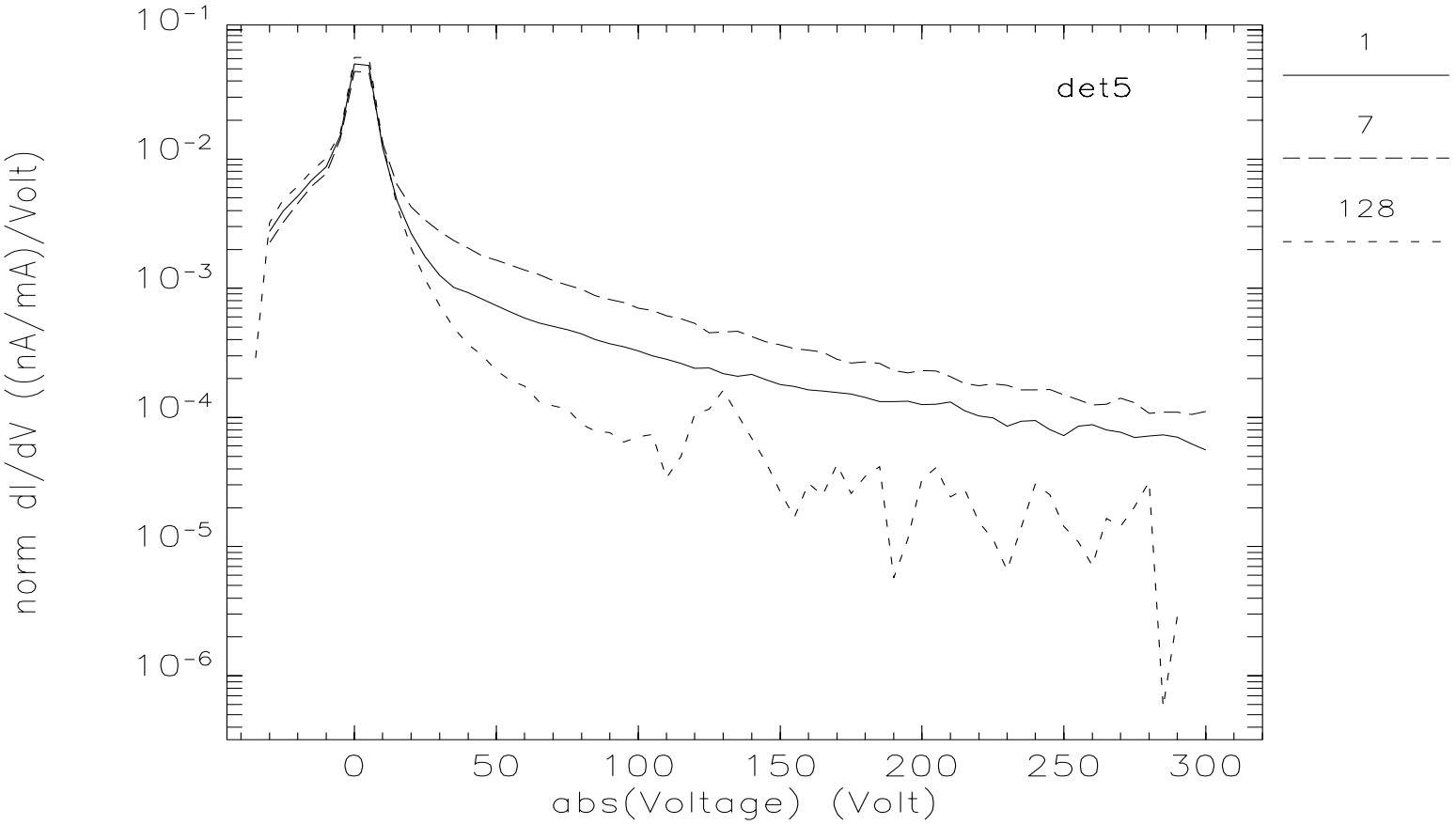
Detector current as a function of distance from EA6, bunches widely spaced (few secondary elecrtons)



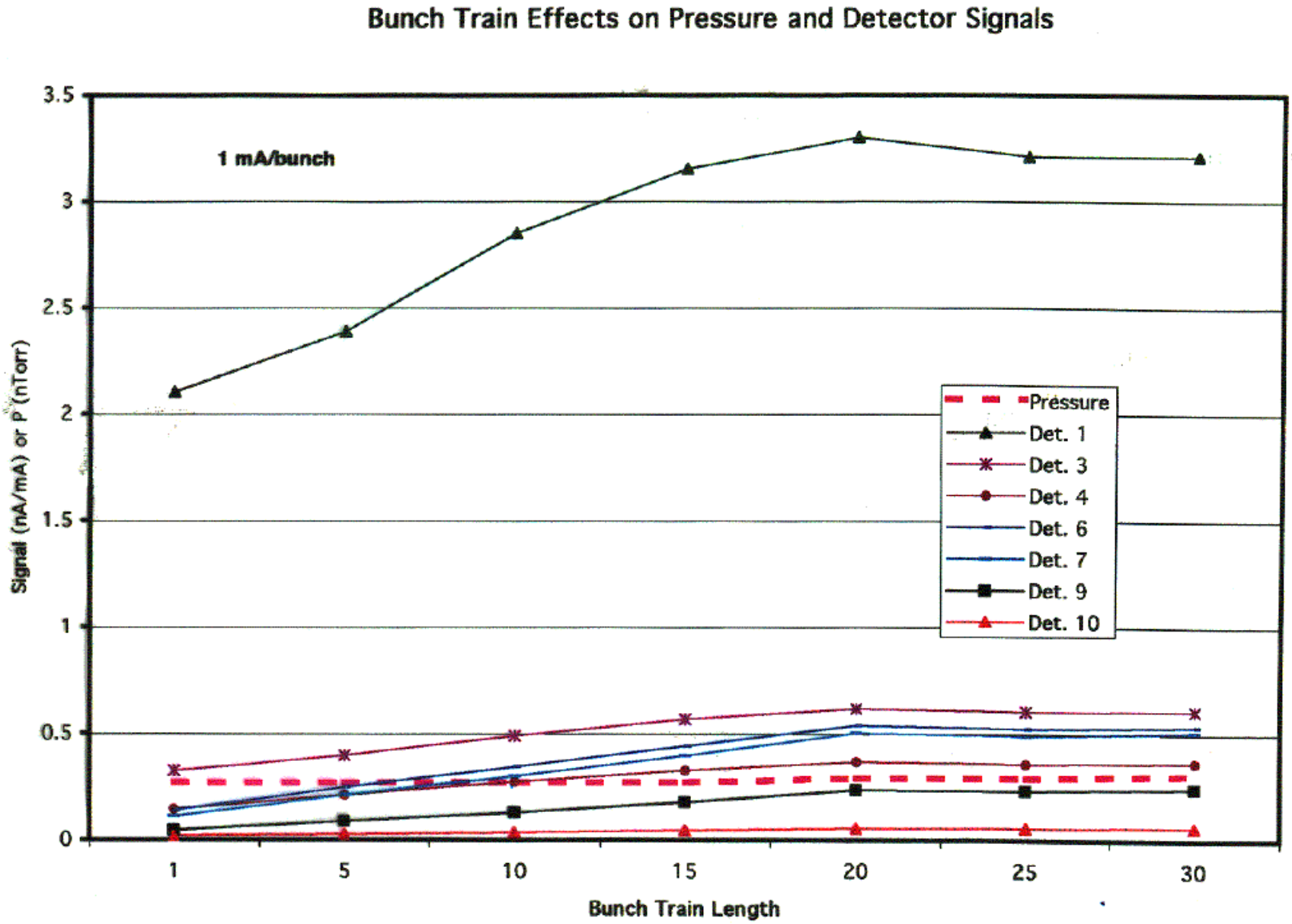
Total, normalized electron current per detector vs. distance from EA6 as a function of bunch spacing (10 bunches, 20 mA). Strong amplification for a bunch spacing, t_b, of 20 ns; by comparison:

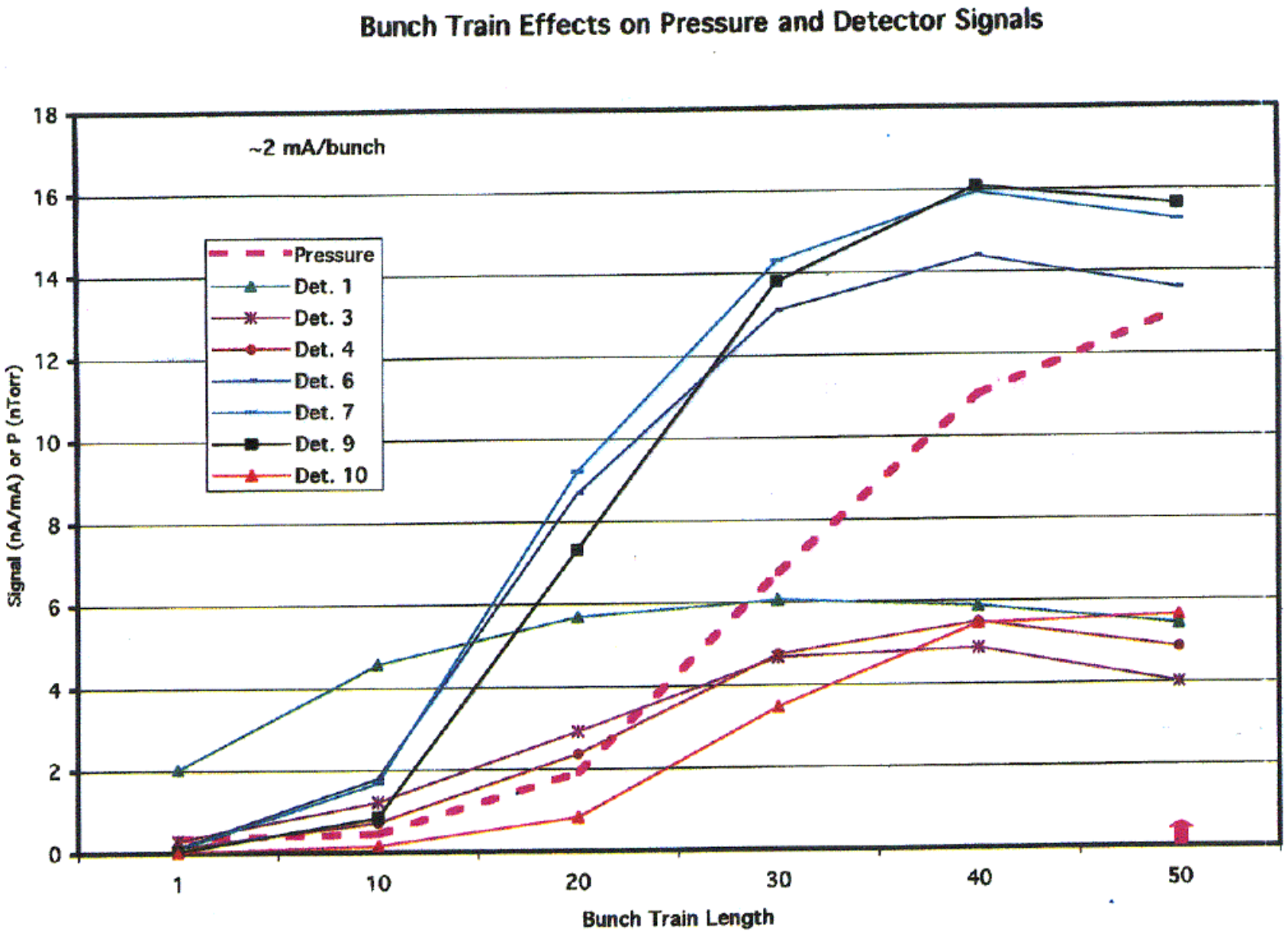
PEP-II: chamber HH (SS) 45 mm; t_b = 13 ns

LHC: chamber HH (Cu) 22 mm; t_b = 25 ns

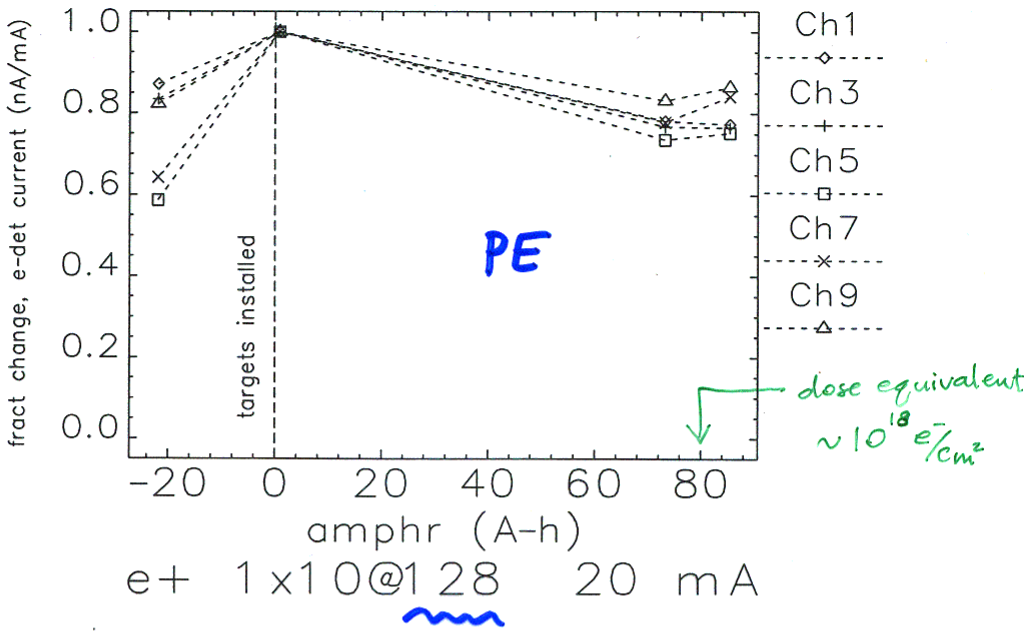


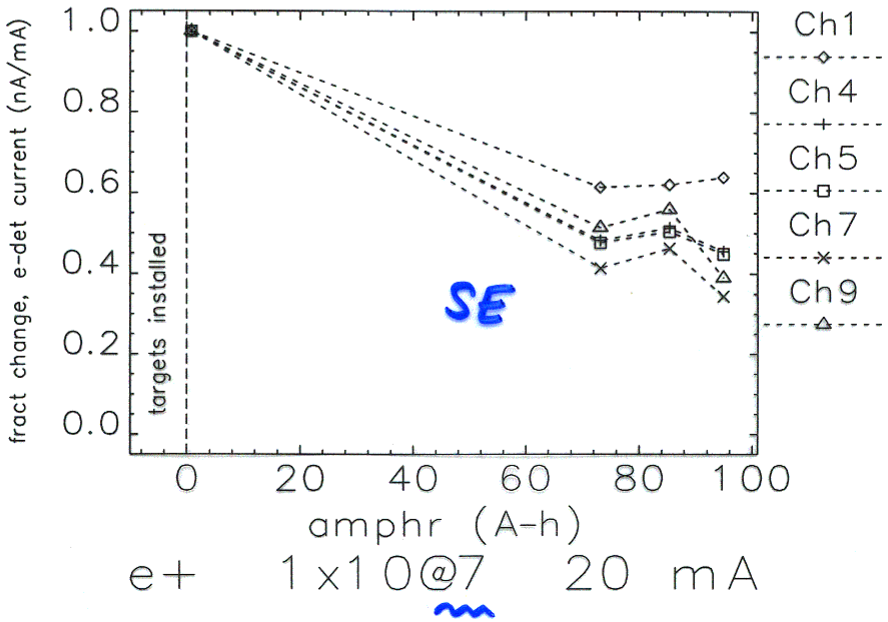
Electron energy distribution vs. bunch spacing

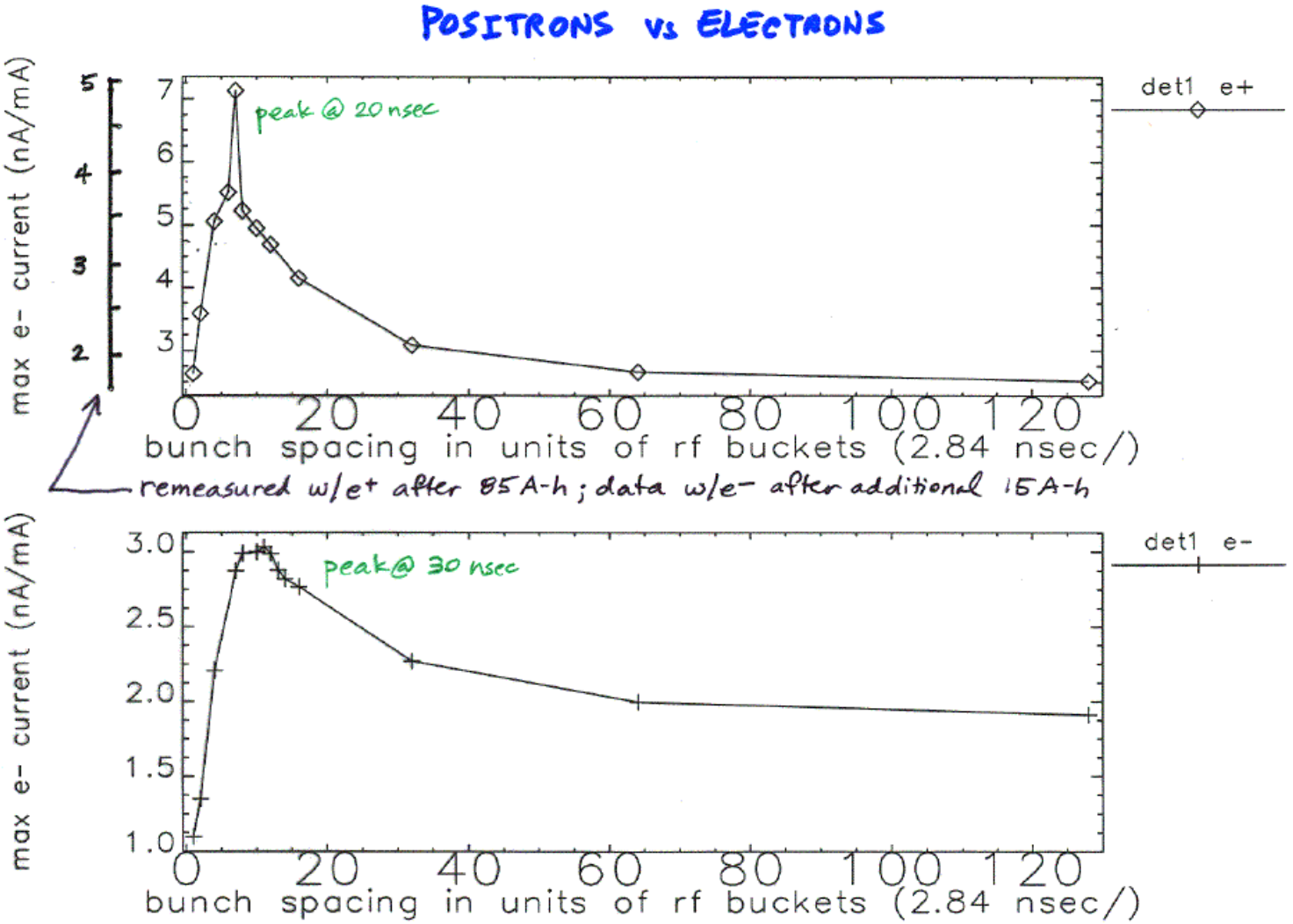

Bunch Train Effects on Pressure and Detector Signals
1 mA/bunch
Signal (nA/mA) or P (nTorr)
3.5
3
2.5
2
1.5
1
0.5
0
1
5
10
15
20
25
30
Bunch Train Length
Pressure
Det. 1
Det. 3
Det. 4
Det. 6
Det. 7
Det. 9
Det. 10

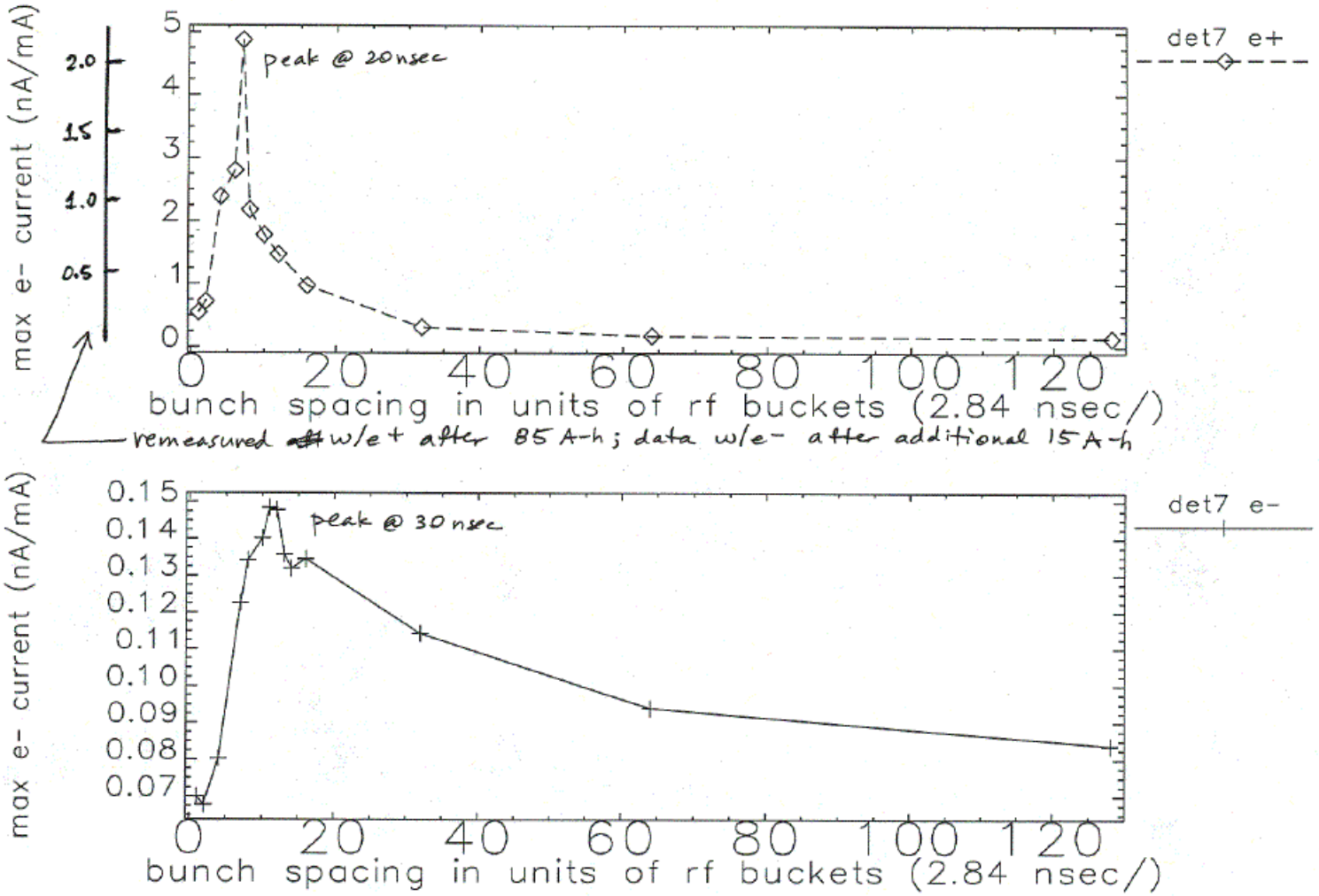

Bunch Train Effects on Pressure and Detector Signals
~2 mA/bunch
Pressure
Det. 1
Det. 3
Det. 4
Det. 6
Det. 7
Det. 9
Det. 10
Signal (nA/mA) or P (nTorr)
Bunch Train Length
0
2
4
6
8
10
12
14
16
18
1
10
20
30
40
50

SURFACE CONDITIONING






POSITRONS vs ELECTRONS
max e- current (nA/mA)
peak @ 20 nsec
det1 e+
bunch spacing in units of rf buckets (2.84 nsec/)
remeasured w/e+ after 85A-h; data w/e- after additional 15A-h
peak@ 30 nsec
det1 e-


max e- current (nA/mA)
2.0
1.5
1.0
0.5
5
4
3
2
1
0
peak @ 20nsec
det7 e+
0 20 40 60 80 100 120
bunch spacing in units of rf buckets (2.84 nsec/)
remeasured w/e+ after 85 A-h; data w/e- after additional 15 A-h
max e- current (nA/mA)
0.15
0.14
0.13
0.12
0.11
0.10
0.09
0.08
0.07
peak @ 30 nsec
det7 e-
0 20 40 60 80 100 120
bunch spacing in units of rf buckets (2.84 nsec/)

ANALYSIS

- Energy gain of electrons at wall accelerated by passing bunch (impulse kick approx):

$$\left(\frac{v}{c}\right)_{\max} = \frac{2N_b r_e}{a} \quad ; \qquad K = \frac{mv^2}{2} = 10 \text{ eV} \quad ; \qquad \text{time to traverse } 2a = 21 \text{ ns}$$

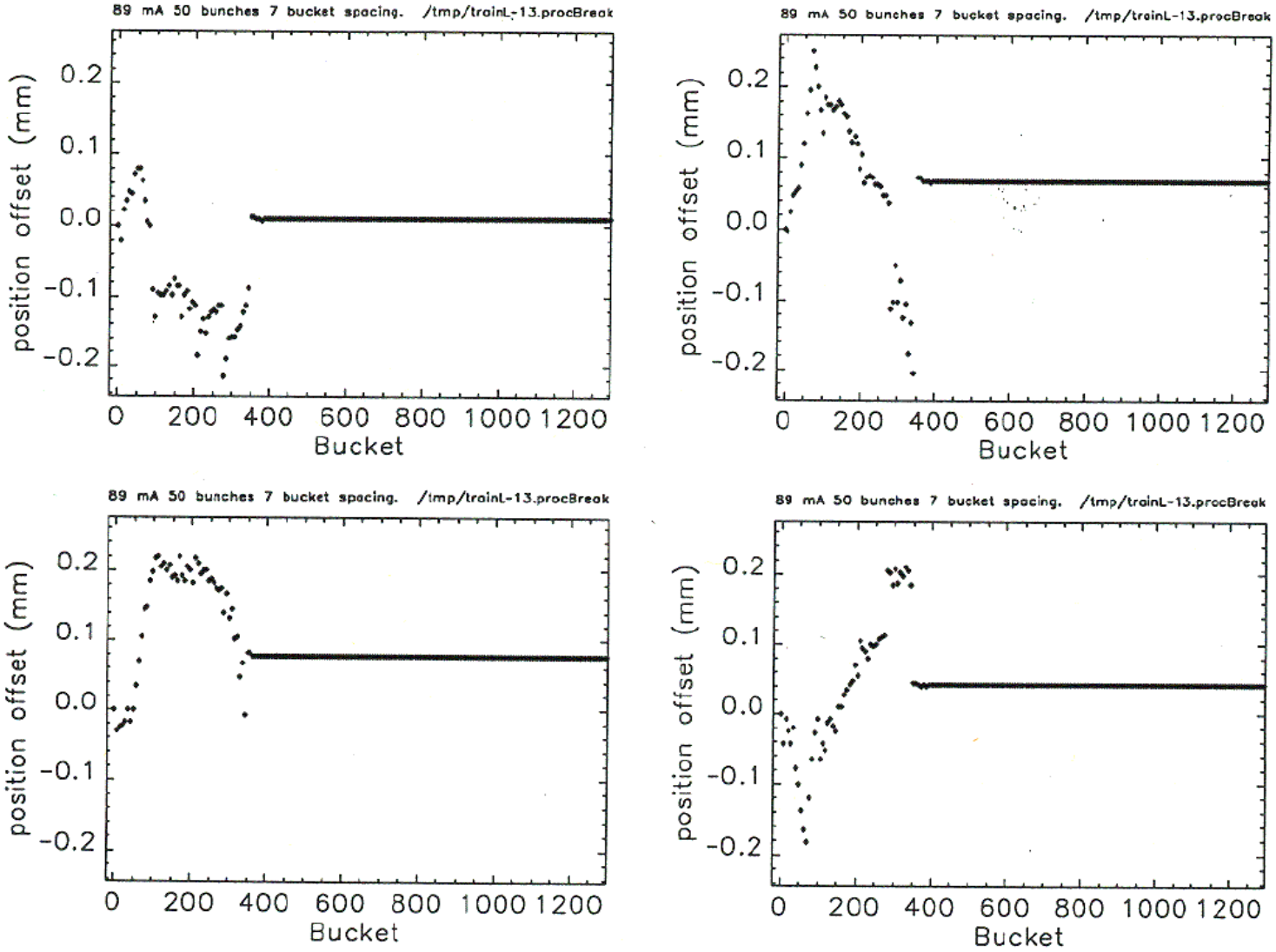
where $N_b = 4 \times 10^{10}$ (2 mA/bunch); $r_e = 2.8 \times 10^{-15}$ m; a = half V aperture 0.021 m

- Approx. electron cloud density from bombardment rate at wall (detector) (per mA):

$$\rho = \frac{\text{rate}}{vA} = 10^2 \text{ e-/cm}^2$$

where rate = 1 nA = 6×10^9 e-/sec; velocity = 2×10^8 m/s (10 eV); Area = 1 cm^2

- Calibration of electron cloud density: target photo-current vs. detector signal
- Simulation studies underway w/code developed at LBNL (M. Furman)
- Comparison with PEP-II results (M. Furman, S. Heifets)



Digitized transverse bunch position in a bunch train (4 consecutive turns) (e+, 50 bunches, 7-rf-bucket spacing, 89 mA). Max e-cloud for these conditions, but is this ECI?

SUMMARY

- Strong dependence of electrons on location; chamber structures (e.g. end absorbers) are local sources of primary electrons
- Energy analysis of cloud enables distinction between primary and secondary components of distribution
- Beam-induced multipacting observed for BOTH positrons and electrons (lower amplification for latter); consistent with expected kinetic energy of cloud electrons
- Bunch current-dependent saturation of electron cloud over bunch trains
- Surface conditioning; different for primary and secondary components
- Collective horizontal motion for long e+ bunch trains; driving source still under investigation (ECI or normal wakefield?)
- Pressure rise resulting from multipacting reduces the lifetime; need to avoid certain electron bunch spacings